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Editorial

Connecting people to connect landscapes

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Linear transport infrastructure (LTI) networks—including roads, railways, navigation canals, irrigation systems, and power lines—are vital for socio-economic development, human convenience, and overall prosperity (Srinivasu and Rao 2013; Skorobogatova and Kuzmina-Merlino 2017). However, much of this infrastructure, particularly in the last few decades, has been constructed with little regard for its adverse effects on biodiversity and wildlife movement (van der Ree et al. 2015; Torres et al. 2016; Bennett 2017). Additionally, the cumulative impact of multiple infrastructure networks at the landscape level, combined with other man-made and natural barriers, has often been overlooked (Papp et al. 2022a).

Although the approach to LTI development has evolved as the shortcomings of earlier practices became evident, significant challenges remain in effectively integrating biodiversity considerations into both the modernization of existing infrastructure and the planning of new projects (Hlaváč et al. 2019; Rosell et al. 2023). Key obstacles include a lack of strong cooperation between stakeholders, insufficient transparency, weak stakeholder engagement, and a general lack of motivation to address biodiversity concerns. Overcoming these challenges requires fostering transdisciplinarity (Papp et al. 2022b), including a culture of collaboration, ensuring meaningful participation, and creating incentives for sustainable infrastructure development that integrates biodiversity and ecosystem services.

The rapid advancement of technology and the push for faster, safer transportation systems often outpaces the ability of transdisciplinary approaches to address other critical concerns, such as wildlife movement across LTI (Seiler and Helldin 2006; Seiler and Bhardwaj 2020). The Infrastructure Ecology Network Europe (IENE) (https://www.iene.info/), founded in 1996, has been a pioneer in promoting a collaborative, transdisciplinary approach to mainstream biodiversity into LTIs. IENE's network includes a diverse range of stakeholders—decision-makers, road planners, environmental authorities, and researchers. IENE provides an independent, international and interdisciplinary platform for developing and exchanging expert knowledge, information and latest advancements, fostering

the development of a safe, integrated and ecologically sustainable pan-European transport infrastructure. One significant way IENE supports the integration of biodiversity into transport networks is through the publication of expert knowledge, showcasing the latest solutions and best practices. A relevant example is the "Biodiversity & Infrastructure: A Handbook for Action" (Rosell et al. 2023), produced under the Horizon 2020 BISON project (https://bison-transport.eu/). This handbook synthesizes over 20 years of experience addressing the impacts of transport infrastructure on biodiversity, offering practical guidelines for designing, upgrading, and operating ecologically sensitive infrastructure. The Handbook is divided into seven chapters covering policy and planning, the mitigation hierarchy, landscape integration, infrastructure solutions, assessment and monitoring, and maintenance. It encourages collaboration across disciplines, having been developed by 50 authors and reviewed by 30 experts from both ecological and infrastructure sectors. By using a shared terminology, it bridges the communication gap between ecologists and infrastructure professionals, fostering mutual understanding and cooperation. It refers to both European and global guidelines to ensure its continued relevance in addressing the challenges of biodiversity protection and climate adaptation. Designed to be flexible and adaptable, the Handbook can be updated as new challenges and solutions arise.

IENE members are actively engaged in developing cutting-edge solutions to prevent wildlife-vehicle collisions, such as alert and warning systems for both drivers and animals (Huijser et al. 2015; Seiler and Olsson 2017), and tools for monitoring the presence of wildlife on roads and railways (Carvalho et al. 2017; Bhardwaj et al. 2020; Shilling et al. 2020). The exchange of such innovative solutions, along with best practices and knowledge aimed at making LTI more sustainable and ecologically friendly, is facilitated through various IENE events, including its biennial conferences held across Europe (Sjölund et al. 2022). At the IENE Conference in September 2022, hosted in Cluj-Napoca, Romania, numerous ground-breaking studies were shared, with a selection of emblematic research published in this Special Issue titled "Connecting People, Connecting Landscapes." These studies tackle crucial topics related to the integration of biodiversity into transport networks, such as the effectiveness of wildlife crossings, the preservation of ecological connectivity at the landscape level, environmental impact assessments for both old and new LTI, animal-vehicle collision prevention, wildlife exclusion from transport networks, and the role of LTI in providing habitat and refuge for wildlife.

IENE has systematically addressed these topics over time, providing guidance for both infrastructure planners and decision-makers to integrate ecological considerations into their projects and policies. For instance, the Global Strategy for Ecologically Sustainable Transport and Other Linear Infrastructure (Georgiadis et al. 2020) outlines specific objectives and principles for governments and organizations to mainstream biodiversity and ecological connectivity in transport infrastructure development. This strategy emphasizes the need for multi-sectoral collaboration, proactive policies, appropriate legal frameworks, and the application of innovative, scientifically sound solutions. The outcomes of the 2022 conference, including the Cluj-Napoca Conference Declaration, further reinforced this direction, calling for strengthened cooperation among stakeholders to ensure that transport infrastructure development aligns with biodiversity conservation and landscape connectivity goals.

Declaration of the IENE 2022 International Conference
Cluj–Napoca, Romania, 19–23 September 2022

We, the participants to the IENE 2022 International Conference in Cluj–Napoca, Romania, acknowledge that:

1. While the transport sector (including infrastructure and energy networks) is crucial to the development of human society, a diverse and functional natural environment is the prerequisite not only for our well-being but ultimately for our survival as a species.
2. The centuries of intensive transport development in Western Europe also taught us how detrimental for nature, and especially wildlife and the coherence of ecosystems and landscapes, this infrastructure could become if it is designed, built or operated in an unsustainable way.
3. The transport sector is closely connected, directly or indirectly, to the five main direct drivers of biodiversity loss[1]:
   i. **Land- and sea-use change**, by irreversibly fragmenting habitats and populations and by increasing wildlife mortality risks and sealed soil, changing the structure and functionality of ecosystems and generating a cascade of changes at landscape levels;
   ii. **Direct exploitation of organisms**, by facilitating access to previously remote natural areas/roadless areas and overexploitation of animals, plants and other organisms, mainly via gathering, logging, hunting and fishing;
   iii. **Climate change**, by increasing green-house gas emissions during the construction and use of the infrastructure;
   iv. **Pollution from all sources**, emitted during the construction and use of the infrastructure; and
   v. **Invasive alien species**, facilitating their introduction and spread.

1 Brondizio ES, Settele J, Díaz S, Ngo HT (Eds) (2019) Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES secretariat, Bonn, Germany. https://doi.org/10.5281/zenodo.3831673

As these drivers are reinforced by underlying causes such as the lack of consistency across sectoral policies, subsidies, and between regulations, there is a strong and urgent need for integrated sustainable approaches and an adequate and effective governance.

4. Although during the past decades the concern about the impacts of the transport sector led to better approaches, adapted techniques and increased expertise on how to plan, build and operate sustainable transport networks, the past issues remained, making Western Europe one of the most fragmented landscapes worldwide, which has led to several countries responding by implementing vast and costly defragmentation programs and plans.
5. In contrast with Western Europe, the Eastern part of the continent is rightfully demanding urgent extension and modernization of its transport infrastructure. At the same time, this area of Europe still holds unique natural and cultural values, productive landscapes and functional ecosystems as a result of predominantly extensive use of natural resources.
6. In the current political and socio-economic context, Eastern Europe and regions like the Balkans and the Black Sea are being presented with a unique possibility: to develop transport infrastructure that does not cause a devastating and costly fragmentation of nature, making the best use of existing knowledge accumulated over the last decades.
7. Moreover, Eastern Europe has the opportunity to become a reference region for overall sustainable development, especially in the critical context of climate change, water shortage, land degradation and biodiversity loss.

WE CALL FOR URGENT ACTIONS, FROM POLICY TO PRACTICE, and invite the entities at all levels (local, national, European and international) of governments, conventions, organisations, academia, institutions, businesses, transport planners, constructors and operators, networks, experts, funders, mass-media and civil society to foster cooperation, in order to:

1. Adopt sustainability in transportation development across the spectrum of human activities in the 21st century as essential under four basic pillars:
   i. The well-being of societies;
   ii. The resilience of healthy economies;
   iii. Environmental quality and safety and the link with effective biodiversity conservation;
   iv. Keeping the impacts of human activities on the environment reversible.
2. Recognize that safeguarding ecological connectivity is a key aim and a major challenge for the transport sector, which needs to be addressed in spatial planning in collaboration with other sectors (i.e., other infrastructure, agriculture, forestry, tourism, hunting, water management, protected areas, etc.).
3. Include as a key objective for sustainability the avoidance of fragmentation of nature and landscapes in all developing activities, in accordance with relevant strategic policy documents and technical recommendations[2].

2 i. The Convention on Biological Diversity 2018 decision on mainstreaming biodiversity in developing sectors including transport.

4. Adopt and implement the principles of the **IENE Global Strategy for Ecologically Sustainable Transport and other Linear Infrastructure**, namely:
   i. Create **a strong policy and legal framework** on safeguarding landscape connectivity as a primary concern for any project scale including regulatory requirements through standardization of tools, methods, etc.;
   ii. Begin with **strategic planning** with the implementation of "Avoidance – Mitigation – Compensation" mitigation hierarchy[3];
   iii. Follow an **ecosystem approach** based on the "Precautionary Principle"[4] respecting the value of natural capital and ecosystem functions and services;
   iv. Evaluate that **any case is a unique case.** Each project is site-and species-specific and therefore unique. Mitigation should be based on scientific and best available local knowledge without "copy paste" from other projects and cumulative impacts of other local projects should be taken in to account;
   v. Enhance **multi-disciplinary and cross-sectoral cooperation**;
   vi. Implement **the responsible polluter pays principle** not only from the pollution perspective, but also taking into consideration the impacts on biodiversity and ecological connectivity as well as ethical and transparency concerns;
   vii. Include **long life effective maintenance** and sufficient monitoring in all planning and budgeting of transport and other developing projects.
   viii. Create **climate change resilient infrastructure**;
   ix. Plan and manage **adaptable infrastructure habitats** to fulfill their potential as positive biodiversity refuges and ecological corridors;
   x. Establish **environmental supervision and monitoring** of the effectiveness of transport infrastructure features on wildlife permeability in all phases of programs, plans and projects;
   xi. Promote a **culture of learning** to develop continuous evaluation and exchange of knowledge and experience.

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ii. The Sustainable Development Goals include addressing biodiversity loss and securing ecological connectivity as essential drivers for sustainability.
iii. The United Nations plans for an active Restoration Decade through 2030.
iv. The EU Strategies for Biodiversity and Green Infrastructure.
v. The EU Green Deal and the implementation of Europe-wide Restoration Goals.
vi. The EC technical guidance on the application of "do no significant harm" under the Recovery and Resilience Facility Regulation, C(2021) 1054 final.
vii. The Carpathian Convention's initiatives on Sustainable Transportation, Biodiversity conservation and ecological connectivity.
viii. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) global assessment (2019) found that of the five pressures on biodiversity, the most important on terrestrial environments was land-use change, which may include deforestation, intensification in agricultural management, or habitat fragmentation.
ix. Experts from the Intergovernmental Panel on Climate Change (IPCC) and IPBES met in 2020 and concluded that none of the issues identified by these two platforms can be solved if they are not addressed together.

3 See the Glossary of the Working Group on No Net Loss of Ecosystems and their Services: https://ec.europa.eu/environment/nature/biodiversity/nnl/index_en.htm

4 https://eur-lex.europa.eu/EN/legal-content/summary/the-precautionary-principle.html

5. Develop an urgent common framework of priority actions from policy to practical implementation of evidence-based solutions to mainstream biodiversity into a sustainable transport sector, such as:
   i. Support the appropriate political will for taking decisions based on criteria of the four pillars of sustainability and biodiversity conservation needs;
   ii. Think globally and implement policies locally while filling the gaps and overcoming barriers that have been highlighted by relevant transport & ecology projects (e.g., BISON[5], TRANSGREEN[6], ConnectGREEN[7], SaveGREEN[8], HARMON[9], among others);
   iii. Cooperate to enable the coexistence of ecological and transport corridors through the implementation of EU TEN-G[10], TEN-N[11] and TEN-T[12] Strategies while effectively sharing experience and know-how between countries and entities across Europe and globally;
   iv. Develop cross-sectoral tools and management practices for effectively protecting the coherence of the ecological networks (e.g., NATURA 2000, Emerald) and the integrity of their component sites and of other protected areas (e.g., parks or reserves);
   v. Proactively produce and use the scientific and practical knowledge to promote innovative and sound evidence-based sustainable solutions and make use of updated data bases, modern standards and innovative methodologies;
   vi. Include in the necessary assessments (e.g., Strategic Environmental Assessments, Environmental Impact Assessments, Appropriate Assessments, Climate Change, or Water Framework Directive Assessments) independent scientific expertise and environmental supervision while involving the local society and the relevant stakeholders;
   vii. Implement the appropriate measures to avoid, reduce and compensate the impacts on biodiversity, based on multidisciplinary cooperation between social scientists, environmentalists and engineers in order to achieve infrastructure sustainability, resilience and acceptability at landscape level.

Cluj-Napoca, Romania, September 2022

5 https://minuartia.com/en/the-horizon-2020-project-bison-presents-final-results-at-the-european-council-in-strasbourg/

6 https://dtp.interreg-danube.eu/approved-projects/transgreen

7 https://dtp.interreg-danube.eu/approved-projects/connectgreen

8 https://dtp.interreg-danube.eu/approved-projects/savegreen

9 https://green-web.eu/projects/harmon/

10 https://environment.ec.europa.eu/topics/nature-and-biodiversity/green-infrastructure_en#:~:text=Green%20infrastructure%20has%20been%20defined,example%2C%20water%20purification%2C%20improving%20air

11 https://www.eea.europa.eu/publications/building-a-coherent-trans-european

12 https://transport.ec.europa.eu/transport-themes/infrastructure-and-investment/trans-european-transport-network-ten-t_en

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

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Papp CR designed the manuscript and developed the first draft, the other authors contributed with input and feedback. Papp finalised the article.

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Data availability

All of the data that support the findings of this study are available in the main text.

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